DEVELOPMENT OF COMPRESSED AIR POWERED ENGINE SYSTEM BASED ON SUBARU EA71 MODEL

CHEN RUI

A project report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITY MALAYSIA PAHANG

JUNE 2013

UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled DEVELOPMENT OF COMPRESSED AIR POWERED ENGINE SYSTEM BASED ON SUBARU EA71 MODEL is written by CHEN RUI. I have examined the final copy of this report, and in my opinion, it is fully adequate in terms of language standard, and report formatting requirement for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Prof. Ir. Dr. Hassan Ibrahim

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project, and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature :
Name of Main Supervisor : Gan Leong Ming
Position : Senior Lecturer
Date :

Signature :
Name of Co-Supervisor : Pr. Dr. Haji Rosli Bin Abu Baka
Position : Professor
Date :

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature :
Name : Chen Rui
ID Number : MH09095
Date :

TABLE OF CONTENTS

		Page
EXAMINER'S DECLARATION		ii
SUPERVISOR'S DECLARATION		iii
STUDENT'S DECLARATION		iv
ACKNOWLEDGEMENTS		vi
ABSTRACT		vii
ABSTRAK		viii
TABLE OF CONTENTS		ix
LIST OF TABLES		xii
LIST OF FIGURES		xiii
LIST OF SYMBOLS		xv
CHAPTER 1	**INTRODUCTION**	
1.1	Background Study	1
1.3	Problem Statement	2
1.3	Objectives	3
1.4	Scopes	3
1.5	Hypothesis	3
1.6	Flow Chart	4
CHAPTER 2	**LITERATURE REVIEW**	
2.1	Conventional Internal Combustion Engine	5
	2.1.1 Engine systems	5
	2.1.2 Working process of 4-stroke engine and 2-stroke engine	6
	2.1.3 Flat four engine	7
2.2	Fundamental of Compressed Air Engine	7
2.3	Development of Compressed Air Engine	8

2.4	Compressed Air Technology (CAT)	8
2.5	Construction of Compressed Air Engine	10
2.6	Working Process of Compressed Air Engine	12
2.7	Air Engine Cycle	14
2.8	Governing Parameters & Equations	18
2.9	Advantages & Shortages	20

CHAPTER 3 METHODOLOGY

3.1	3D Reverse Engineering	21
	3.1.1 Engine overhaul & cleaning	21
	3.1.2 3D drawing process	22
3.2	Definition of Air Cycle	23
	3.2.1 Theoretical air cycle	24
	3.2.2 Prediction air cycle	25
3.3	Design of Compressed Air Powered Engine Model	27
3.4	Software Computation Analysis	28

CHAPTER 4 RESULT AND DISCUSSION

4.1	3D Reverse Engineering	33
4.2	Air Powered Engine Design	33
4.3	GT Power Computation Analysis	35

CHAPTER 5 CONCLUSION

5.1	Conclusion	49
4.2	Recommendation	50

REFERENCES 51

APPENDICES

A	Gantt chart	52

B	List of engine components after dismantling and cleaning	53
C	List of engine components drawing in Solidworks	56
D	List of plots in GT-Post	61

LIST OF TABLES

Table No.	Title	Page
2.1	Technical Specification of CAT Vehicle	9
2.2	Components of Compressed Air Engine	11
2.3	Compressed Air Powered Compact CAFS (Truck Carried)	18
4.1	Engine Geometry	40
4.2	Engine MEP, Torque and Power	41
4.3	Engine Operation Condition	42
4.4	Engine Performance Predictions	42
4.5	Key Cylinder Predictions	43
4.6	Gas-Structure Heat Transfer	44

LIST OF FIGURES

Figure No.	Title	Page
2.1	A two-stroke free piston linear generator engine	6
2.2	Flat-Four Engine Piston Position	7
2.3	MDI Designed Air Engine	10
2.4	Dwelling Connecting Rod	13
2.5	Air Engine P-V Diagram – 1	14
2.6	P-V Diagram of Air Engine - 2	16
3.1	Cam Profile Measuring	23
3.2	Theoretical Air Cycle P-V Diagram	24
3.3	Air Powered Cylinder Theoretical Working Process	24
3.4	Prediction Air Cycle P-V Diagram	26
3.5	Air Powered Cylinder Prediction Working Process	26
3.6	Piston and Cylinder Geometry of Reciprocating Engine	30
3.7	Instantaneous Piston Speed Relative to Average Piston Speed as a Function of Crank Angle for Various R Values	30
3.8	Force Position	31
4.1	New Design of Camshaft	34
4.2	New Design of Cylinder Head	34
4.3	Design of Separation Port	35
4.4	Templates for Air Engine in GT Power	36
4.5	Setting of Intake Valve	37

4.6	Theta Array and Lift Array	38
4.7	Indicated Power, Indicated Torque and IMEP Change Curve with Different Intake Valve Open Angle	39
4.8	Valve Timing Graph	41
4.9	Pressure and Temperature Curve in the Cylinder	45
4.10	Fluid to Wall Heat Transfer Rate	46
4.11	P-V Diagram	47

LIST OF SYMBOLS

A	Cross-section area of piston
B	Bore
BP	Brake power
BMEP	Brake mean efficiency pressure
CR	Cylinder compression ratio
CTA	Cam timing angle
EVO	Exhaust valve open angle
$h_{clearance}$	Clearance height
IVO	Intake valve open angle
IMEP	Indicated mean efficiency pressure
K	Number of strokes
L	Stroke length of piston
m	Mass of gas
m	Slope of P-V curve after TDC
n	Amount of substance of gas
η_v	Volumetric efficiency
η_{map}	Volumetric efficiency from the table
N	Engine speed, rpm
N	Crankshaft rotational speed
P	Pressure of gas
P	Power
P	Instantaneous cylinder pressure between TDC and the transition point
P_b	Brake power
P_{comb}	Pressure rise due to combustion
P_i	Indicated power
P_i	Pressure in upstream volume
$P_{i,map}$	Intake pressure from the table
P_{max}	Maximum cylinder pressure (pressure at TDC)
P_{IVC}	Cylinder pressure at IVC

PR	Pressure ratio (exh/int) across the cylinder
PR_{map}	Pressure ratio (exh/int) from the table
R	Gas constant for a particular gas
R	Ratio of the connecting rod length to crank offset
S	Stroke
t	Off-load time in minutes
T	On-load time in minutes
T	Temperature of gas
T	Torque
T_i	Temperature in upstream
$T_{i,map}$	Intake temperature from the table
$\overline{U}_p$	Mean piston speed
U_p	Indicated piston speed
v	Specific volume
V	Volume of gas
V	Engine displacement
V	Instantaneous cylinder volume between TDC and the transition point
$V_{pistoncup}$	Piston cup volume
$V_{headregion}$	Head region volume
V_{TDC}	Cylinder volume at TDC
W_i	Indicated work
ω	Shaft angular velocity
γ	Ratio of specific heat values for the intake air
γ	Specific heat ratio
η	Mechanical efficiency
η_R	Number of crank revolutions per cycle